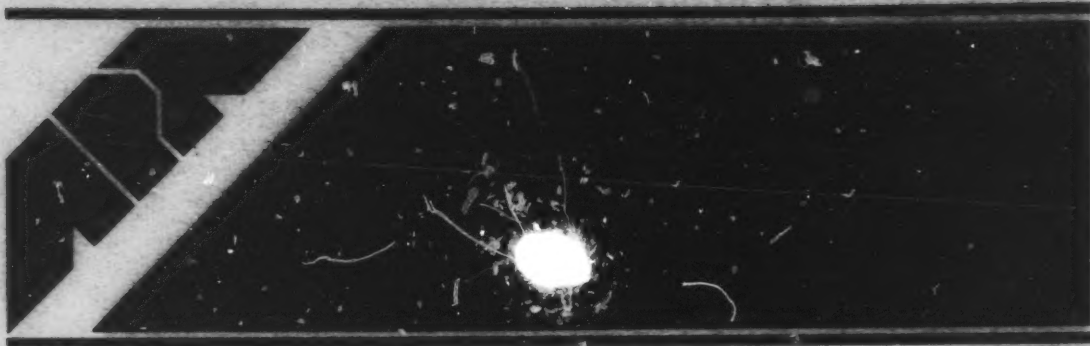
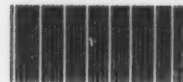


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**TP 11381E  
TILTROTOR/VERTIPORT PLANNING  
AND DEVELOPMENT IN CANADA  
SUMMARY REPORT**

Prepared for the  
**Transportation Development Centre  
Policy and Coordination  
Transport Canada  
June 1992**



by:

**APA Airport Planning Associates Inc.**

492848

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*The contents of this report reflect the views of APA Airport Planning Associates Inc. and not necessarily the official views or opinions of the Transportation Development Centre of Transport Canada.*

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*Ce sommaire est aussi disponible en français:*

*Etude de planification et d'implantation d'aéroports et de services de transport par avion convertible à rotors basculants au Canada, TP 11349F.*

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| 16. Résumé<br><b>Le présent rapport dresse un tableau général de la technologie des appareils convertibles à rotors basculants et de ses applications possibles au Canada. Il fait le survol de l'évolution et de l'état actuel de la technologie des rotors basculants, la description de l'appareil et de ses caractéristiques opérationnelles, un inventaire exhaustif et cohérent des critères et des paramètres à prendre en compte dans la planification des installations et des procédures devant mener à l'implantation de services de transport par avion convertible à rotors basculants au Canada, ainsi qu'une analyse du marché potentiel de ces services au Canada. Le rapport ne traite pas spécifiquement de l'exploitation commerciale de ces avions ni des coûts d'une telle exploitation, et passe sous silence les questions relatives à la certification des appareils et à la délivrance des licences de pilotes.</b> |                                                                         |                                                                                                            |                                      |                      |
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# **TILTROTOR/VERTIPORT PLANNING AND DEVELOPMENT IN CANADA SUMMARY REPORT**

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## TILTROTOR/VERTIPORT PLANNING AND DEVELOPMENT IN CANADA SUMMARY REPORT

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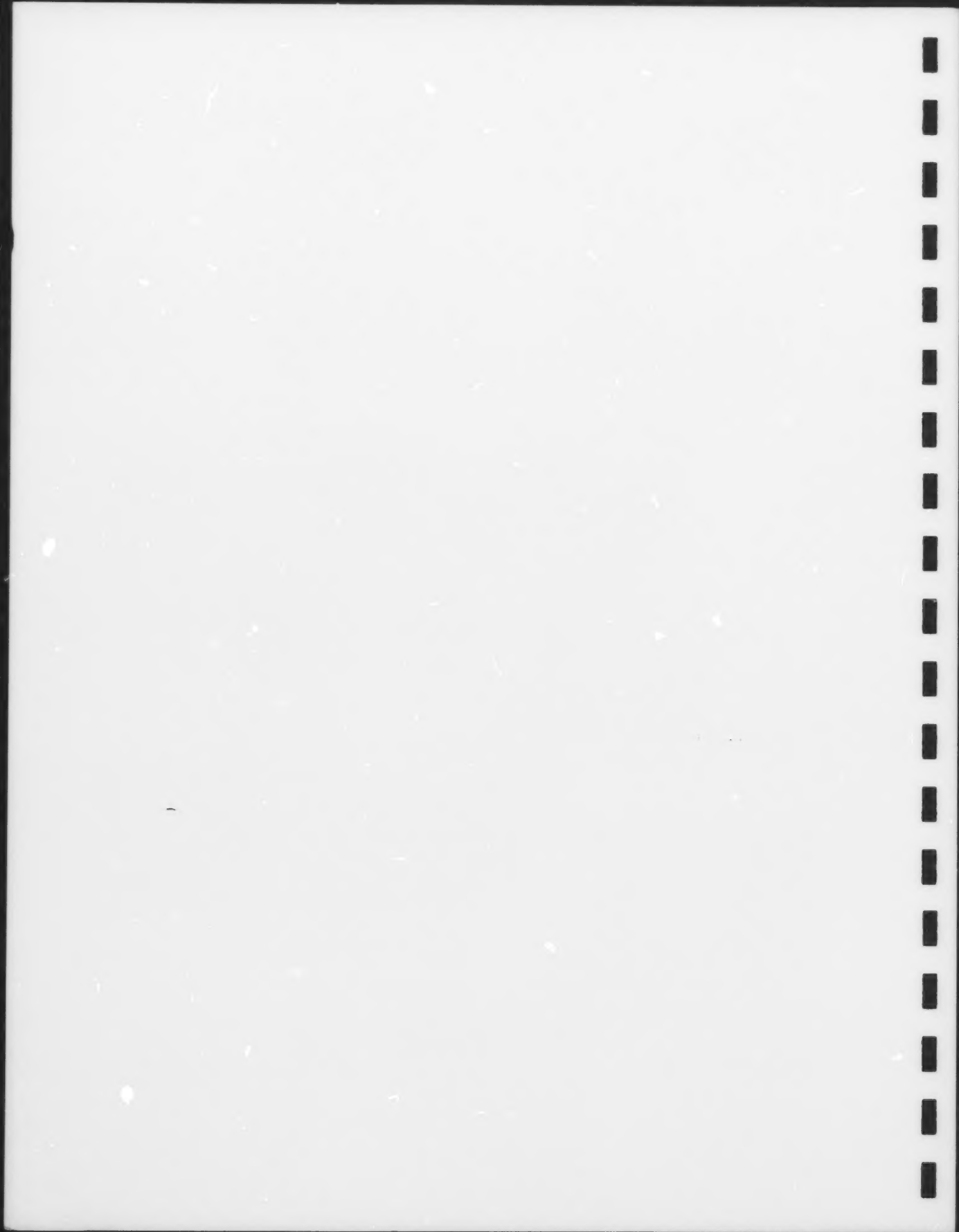
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## 1. INTRODUCTION

### 1.1 Background of the Study

Tiltrotor technology offers some of the most innovative and potentially valuable advances in aviation since the advent of the jet engine. These aircraft represent a "third stream" in the development of air transportation, alongside fixed-wing and helicopter craft. With their proprotor assemblies capable of tilting from a vertical to a horizontal alignment vis-à-vis the fuselage, tiltrotor aircraft constitute in many respects a hybrid of these two. This feature enables tiltrotors to combine the manoeuvrability of helicopters with the cruising speed of fixed-wing aircraft (300 mph). When in horizontal position, the proprotors mounted at its wing tips permit the aircraft to lift off, hover and land like a helicopter; when the blades tilt forward, the aircraft accelerates and cruises at high speed (Figure 1).

The new technology is seen as a significant aid to solving the ground access and airside congestion problems currently plaguing the air transportation system. The aircraft does not require large airports with long runways; instead, specialized vertiports occupying a fraction of the space will permit the aircraft to provide direct air service in places where this is not now feasible: city centers, remote sites, rugged terrain, etc. Tiltrotor services may operate at conventional airports, but they are also expected to give rise to entirely new facilities, called vertiports, which may be developed on as little as 4 acres of land. Recognizing the ultimate role of CTR services at an early stage of system development and properly incorporating future requirements into the long-term planning process will enable appropriate sites within cities to be safeguarded with minimum public investment, by encouraging urban development compatible with vertiport operations.

The technical feasibility of tiltrotor technology was first demonstrated in 1958 when Bell Helicopter produced the XV-3. In 1979, the XV-15 tiltrotor test vehicle developed by Bell in response to U.S. Army requirements commenced an intensive long-term evaluation programme. More recently, a joint team of Bell Helicopter Textron and Boeing Helicopter has undertaken a major programme to develop a multi-mission tiltrotor aircraft for the U.S. Department of Defense and has successfully produced and flown prototypes of this vehicle, the V-22 Osprey.

In order for CTR technology to contribute to the enhancement and efficiency of the air transportation system of the 21st century, it must ultimately be capable of operating in IFR conditions (near-zero visibility, etc.), in the constrained airspace usually associated with urban vertiport sites and at locations which are attractive to the air passenger market. In order to minimize vertiport land and airspace requirements, CTR will have to be able to operate safely from minimum vertiport facilities (zero field length) and satisfy FAA Transport Category A requirements.

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**FIGURE 1**  
**BASIC MODES OF TILTROTOR FLIGHT**

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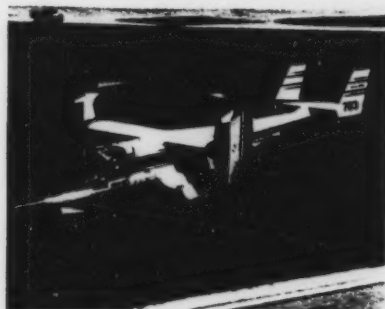
AIRPLANE MODE: STANDARD LEVEL FLIGHT



TILTROTOR MODE: TRANSITION STAGE



HELICOPTER MODE: VERTICAL FLIGHT



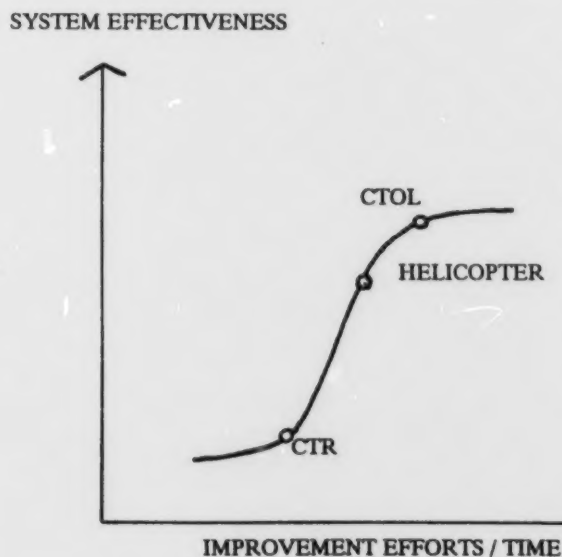
Considering the relative position of CTR technology vis-à-vis that of helicopters and conventional aircraft on the typical "S" curve of the general pattern of technological development (Figure 2), our long-term view must not be overly influenced by the operational limitations of the CTR vehicles currently being developed. One must look beyond the capabilities of the first generation of CTR vehicles and properly integrate foreseeable improvements of CTR technology into the long-term planning process in order to capitalize on the special inherent characteristics of this technology. The same attitude must be applied when considering the necessary technological advancements of other related components of an eventual CTR air transportation system such as the development of advanced navigation aids.

Civil derivatives of this aircraft, as well as other tiltrotor craft, have been proposed for a number of roles which would expand and enhance civil aviation throughout the world, by taking advantage of the unique flying capabilities of the vehicle. The U.S. Congress, in response to the findings of studies by the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), the Department of Defense

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**FIGURE 2**  
**GENERAL PATTERN OF TECHNOLOGICAL DEVELOPMENT**

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(DOD), the Port Authority of New York and New Jersey (PANYNJ), Bell Helicopter Textron and Boeing Aircraft, has mandated the FAA to coordinate a special nation-wide programme to advance the development of civil tiltrotor. As part of this mandate, FAA has publicly invited other countries to participate in the effort to aggressively develop and implement a civil tiltrotor (CTR) air transportation system in order to (1) alleviate conventional airport and airways congestion, (2) provide improved downtown-to-downtown transportation and (3) enhance the accessibility of air services to difficult sites.

A number of tiltrotor development and application programmes are currently being actively pursued by airport authorities, civil aviation agencies, aircraft manufacturers and research organizations on an increasingly global basis. The present study explores planning criteria and parameters for the development of civil tiltrotor/vertiport air services and examines the applications and feasibility of civil tiltrotor in Canada. It complements a number of other studies conducted in the United States. It is expected that this study will assist in decisions concerning the selection, development and analysis of sites which could eventually be suitable for Canadian tiltrotor air service in conjunction with an eventual FAA demonstration programme.

## **1.2 Objectives and Scope of the Study**

The principal objectives of the present study are:

- 1) to provide decision-makers with a concise, complete and coordinated description of tiltrotor air transportation: historical progress, current status and expected future development; characteristics of the CTR vehicle; type of service to be provided; special infrastructure requirements; potential for enhancement of the overall air transportation system in Canada;
- 2) to explore planning criteria and parameters for the development of civil tiltrotor/vertiport air services applicable to the Canadian context;
- 3) to assess the market potential of the application of this technology as a means of providing regular scheduled air service in Canada.

### 1.3 Project Documentation

The present **Summary Report** provides a brief résumé of the background, approach and findings of the study and complements the **Main Report**. Together, these documents draw a general portrait of CTR technology and its possible applications in the Canadian context, including a review of the evolution and current status of tiltrotor technology, a description of the vehicle and its operational characteristics, a complete and coordinated presentation of the criteria and parameters necessary for the planning of facilities and procedures to accommodate CTR services in Canada and an analysis of Canadian market potential for CTR services. It does not devote any particular attention to those aspects which relate to airline operations and economics, nor does it consider the issues of civil certification of CTR aircraft and pilots.

### 1.4 Approach and Methodology

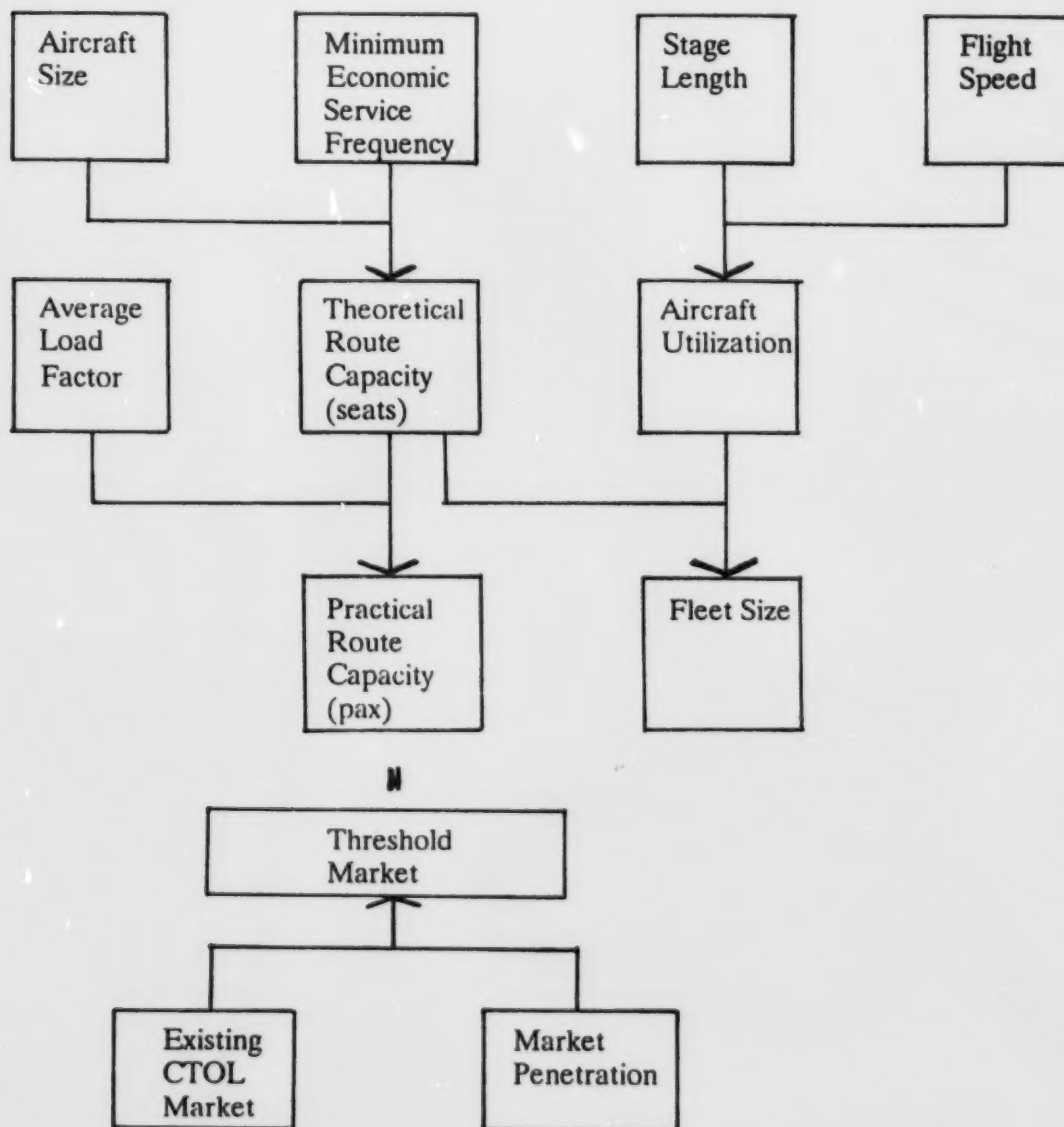
The general approach of the present study involved gathering substantive data on the critical aspects of tiltrotor technology, especially with respect to planning criteria and parameters, from the widest possible range of sources. This was accomplished by means of an extensive survey of aircraft manufacturers and designers, as well as civil aviation, transportation and scientific agencies in North America, Europe and Japan. The resulting data were organized and adapted to take into account the specificities of the Canadian context. Areas covered included aircraft operations, air navigation and vertiport requirements and environmental concerns.

With respect to the application of tiltrotor technology in the Canadian context, the approach of the study involved a quantitative analysis of the market for intercity CTR passenger service and a qualitative analysis of the market for CTR services in other sectors (access to remote regions, support for resource development, police and medical emergencies, maritime and border patrol, corporate/executive transportation, small package deliveries, etc.). More specifically, the methodology employed in the quantitative analysis involved an iterative process in which specific potential city-pair markets were subjected to a series of "filters" based on factors such as the minimum level of traffic necessary to support different types of CTR service, the volume of CTOL traffic, the distance between the cities and other special circumstances and assumed levels of penetration of competing CTOL markets (Figure 3).

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**FIGURE 3**  
**DETERMINATION OF PRIMARY CTR THRESHOLD MARKETS**

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## 2. FINDINGS AND CONCLUSIONS

### 2.1 Development Overview

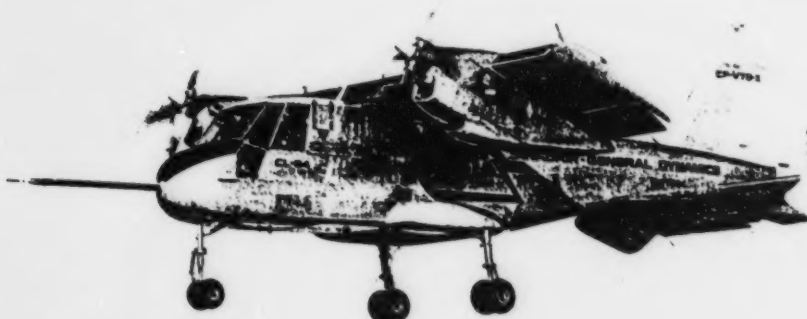
The general perspective with respect to the development and implementation of tiltrotor technology as an air transportation system is that a large number of programmes are being actively pursued by both manufacturers and regulatory and research bodies: Resources to date are those associated with the Bell-Boeing V-22 aircraft, involving Bell Helicopter Textron, Boeing Commercial Airplane Co., the FAA, NASA the US DOD and numerous others. Japanese, European and other US groups are also pursuing vehicle development programmes. Of particular interest to Canadians is the Ishida Corporation TW-68, which is a clear derivative (and openly acknowledged as such) of the tilt-wing CL-84, which was developed by the Montreal-based Canadair aerospace manufacturer (Figure 4).

At the same time, FAA, NASA, manufacturers and other experts from the rotorcraft community have set up a number of coordinated programmes designed to ensure that a complementary infrastructure of vertiports and CNS systems can be developed in order to derive maximum benefit from the unique operational advantages of the tiltrotor: These programmes include ATC procedures, navigational equipment, standards, vertiport site studies and many others (Table 1).

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**FIGURE 4**  
**CANADAIR CL-84 TILT WING AIRCRAFT**

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**TABLE 1**  
**CURRENT CTR DEVELOPMENT PROGRAMMES**

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**Vehicle Development Programmes**

Bell-Boeing: V-22 Osprey programme  
NASA: Rotorcraft Research and Technology Development Program  
FAA: National Civil Tiltrotor Initiative Program  
EUROFAR: Tiltrotor commercial air transport aircraft  
Ishida Corporation: Tilting wing T-68 aircraft  
MAGNUM T/R: Civil adaptation of Bell XV-15 test aircraft  
E.H. Industries: EH-101 helicopter  
McDonnell Douglas Helicopter Company: MD-900 advanced helicopter design  
Sikorsky Helicopter: Civil transport helicopter design  
USSR: Tilt-wing aircraft development

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**Vertiport Siting Requirements and Planning Studies**

PANYNJ: Feasibility of tiltrotor use at the three airports of the New York area  
PANYNJ: Site study for tiltrotor vertiport in Manhattan  
Washington D.C.: Vertiport/helistop feasibility study  
State of California: State-wide civil tiltrotor aircraft feasibility study  
Southern California Association of Governments (SCAG)  
San Francisco  
State of Texas: Vertiport design study  
Dade County (Florida)  
Puerto-Rico/Caribbean Region  
State of Illinois  
State of Alaska  
St. Louis  
Orlando  
State of South Dakota  
Boston  
Montreal

---

**CTR Infrastructure and Air System Requirement Programmes**

AHS/FAA (Vertiport Working Group): Vertiport Design Advisory Circular AC150/53xx-xx  
FAA: National Civil Tiltrotor Implementation Plan

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## 2.2 CTR Vehicle

The only examples of tiltrotor technology currently flying are the US XV-15 test aircraft and V-22 Osprey military aircraft. Although neither of these was explicitly designed for civilian missions, it can be assumed that civil versions of tiltrotor aircraft will incorporate all of the necessary amenities: adequate headroom, carry-on baggage storage, comfortable seat pitch, environmental control, galleys and lavatories. The civil application of tiltrotor technology involves a different set of objectives from those for military application. As an example, the 1987 NASA/Bell-Boeing **CTR Missions and Applications Study** identified the following guidelines for the design of eventual civil-use vehicles.

- . V-22 technology base or derivatives:
  - . twin engines
  - . composite airframe structure
  - . tilting wingtip mounted rotors
  - . fly-by-wire
  - . advanced cockpit displays
- . 600 nm design range, using vertical take-off with one engine inoperative (OEI Hover)
- . 800 nm design range, with rolling take-off from a 750 ft field (STOL)
- . Commuter mission profile with FAR reserve fuel requirements
- . All federal aviation regulations met for safety, including Category A operations
- . Ramp self-sufficiency: airstairs, APU, powerpack
- . 30 seconds emergency excess power rating for the purpose of recovery from single engine failure (OEI)
- . Pressurized fuselage
- . Normal passenger accommodations and amenities:
  - . seating at 30 inch pitch
  - . lavatories and galley (hot meal with beverage)
  - . full cabin pressurization, heating and air conditioning.

These design guidelines were developed on the basis of experience with the V-22 aircraft, commercial aircraft design experience, FAA regulations and input from airlines and other aviation operators. A number of proposed civil configurations for tiltrotor technology have come forth in recent years (Figures 5 and 6). Several civilian derivatives of the V-22 have been proposed as well as other new civilian CTR-type vehicles of various sizes and configurations being developed by other manufacturers (Table 2).

The **Ishida TW-68** is a tilting-wing design, with a capacity of from 9 to 16 passengers, depending on whether it would be deployed in a corporate, commuter or maximum-capacity configuration. The company refers to the aircraft as a dual mode air vehicle (DMAV) shuttle aimed at the corporate/commuter/ express delivery market niches (Figure 7).

To assist in further studies the **EUROFAR** group has developed a baseline configuration, illustrated in Figure 13, capable of carrying approximately 30 passengers with three-abreast seating. In this design, only the rotor blade and axle assemblies would rotate, while the wing-tip nacelles would remain in the same alignment relative to the fuselage (Figure 8).

It seems that a civilian aircraft could be ready for service by 1995 at the earliest, with some programmes (e.g. EUROFAR) aiming for a launch date around the year 2000. The sizes and configurations range from a 6-9 passenger VIP / executive transportation / air taxi to a 75 passenger commercial transport aircraft.

**TABLE 2**  
**CTR AIRCRAFT CHARACTERISTICS**

| Aircraft Model      | Passenger Capacity (seats) | Cargo Capacity (cu. ft) | Fuel Capacity (gal US) | Length (ft) | Width <sup>(1)</sup> (ft) | Height (ft) | TOGW (lbs) |
|---------------------|----------------------------|-------------------------|------------------------|-------------|---------------------------|-------------|------------|
| Bell-Boeing CTR-22B | 31                         | n.a.                    | 1423                   | 57.3        | 84.6                      | 17.6        | 45 120     |
| CTR-22C             | 39                         | 254                     | 1423                   | 68.6        | 84.6                      | 20.6        | 46 230     |
| CTR-22D             | 52                         | n.a.                    | 1485                   | 71.7        | 86.0                      | 23.3        | 49 260     |
| CTR-800A            | 8                          | 32                      | 433                    | 41.5        | 58.2                      | 15.3        | 17 216     |
| CTR-1900            | 19                         | 76                      | 474                    | 46.6        | 65.0                      | 17.0        | 22 800     |
| CTR-7500            | 75                         | n.a.                    | 1860                   | 83.7        | 109.0                     | 27.9        | 79 820     |
| EUROFAR baseline    | 30                         | n.a.                    | n.a.                   | 63.6        | 86.9                      | 19.7        | 30 092     |
| Ishida TW-68        | 9-16                       | n.a.                    | n.a.                   | 39.4        | 36.0                      | 13.4        | 12 500     |
| Magnum MTR-201      | 9                          | n.a.                    | n.a.                   | n.a.        | n.a.                      | n.a.        | n.a.       |

(1) Wing span and rotor diameter

---

**FIGURE 5**  
**CTR CONFIGURATIONS**

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CTR 800

XV-15 Size  
(8 Passengers)



- New High-Wing Design

CTR 1900

New Tiltrotor  
(19 Passengers)



- New Low-Wing Design

CTR22A/B

V-22 Min Change  
(31 Passengers)



- Nonpressurized Fuselage

CTR 22C

V-22 Derivative  
(39 Passengers)



- New Pressurized Fuselage

CTR 7500

New Tiltrotor  
(75 Passengers)



- New Low-Wing Design

**FIGURE 6**

**V-22 OSPREY DERIVATIVES - AIRCRAFT CHARACTERISTICS**



|                              | CTR-22B   | CTR-22C   | CTR-22D        |
|------------------------------|-----------|-----------|----------------|
| No. Passengers               | 31        | 39        | 52             |
| Overall Length (ft)          | 57.3      | 68.6      | 71.7           |
| Wing/Rotor Span (ft/ft)      | 45.8/38.0 | 45.8/38.0 | 48.0/38.0      |
| TOGW (OEI Hover) (lb)        | 45,120    | 46,230    | 49,260         |
| Cruise Speed (kt)            | 240       | 282       | 282            |
| Range (nmi) (OEI Hover)      | 600       | 600       | 280*           |
| Engine                       | T406      | T406      | Growth<br>T406 |
| Takeoff Engine Rating (HP)   | 6805      | 6805      | 7312           |
| 30 sec Emergency Rating (HP) | 8506      | 8506      | 9140           |

\* 600 nmi with 39 passengers

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**FIGURE 7**  
**ISHIDA CORPORATION TW-68 - AIRCRAFT CHARACTERISTICS**

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**Dimensions and Areas**

|                |             |                        |
|----------------|-------------|------------------------|
| Wing Area      | 255 Sq. Ft. | (23.7 M <sup>2</sup> ) |
| Wing Span      | 36 Ft.      | (10.97M)               |
| Wing Chord     | 7.08 Ft.    | ( 2.16M)               |
| T/C Ratio      | 20%         |                        |
| Length         | 39.38 Ft.   | (12M)                  |
| Height         | 13.40 Ft.   | ( 4.08M)               |
| Interior Width | 64"         | ( 1.62M)               |
| Cabin Length   | 15.83 Ft.   | ( 4.82M)               |
| Cabin Height   | 63"         | ( 1.6M)                |

**Design Conditions (Projected)**

|                |         |            |
|----------------|---------|------------|
| Max Speed      | 350 KTS | (646 Km/h) |
| Max Cruise     | 268 KTS | (495 Km/h) |
| Best Range     | 187 KTS | (345 Km/h) |
| Best Endurance | 170 KTS | (314 Km/h) |

**Weights**

|               |             |             |
|---------------|-------------|-------------|
| Max T.O. STOL | 16,500 Lbs. | (7,483 Kg.) |
| Max T.O. VTOL | 12,500 Lbs. | (5,669 Kg.) |

**Passenger Capacity**

|                         |    |
|-------------------------|----|
| Corporate Configuration | 9  |
| Commuter Configuration  | 14 |
| Max Passengers          | 16 |

---

**FIGURE 8**  
**EUROFAR - 30 PASSENGER BASELINE CONFIGURATION**

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|                               |             |
|-------------------------------|-------------|
| ■ Maximum AUW                 | 13650 kg    |
| ■ Empty Mass (fully equipped) | 8750 kg     |
| ■ Empty Mass/Max. AUW         | 64.1 %      |
| ■ Cruise Speed                | 300/335 kts |
| ■ Cruise Conditions           | 7500 m/ISA  |
| ■ Wing Span                   | 15.3 m      |
| ■ Fuselage Length             | 19.4 m      |
| ■ Rotor Diameter              | 11.21 m     |
| ■ Engines: Number             | 2           |
| Type                          | TBD         |
| MCR at SL/ISA                 | 2570 kW     |

### 2.3 Operational Parameters

Tiltrotor aircraft are capable of making vertical, nearly vertical, or extremely short rolling take-offs and landings. On the ground, the CTR aircraft will maneuver on wheels in and out of the gate under its own power. They have a range of about 600 nm (even higher if the vehicle executes a rolling take-off and landing) and a cruising speed of between 240 and 350 kts, depending on the configuration. Most of the tiltrotor aircraft presently under consideration for civil application are designed to operate at cruising altitudes between 16 000 feet and 22 000 feet. This corresponds roughly to the operational altitudes of today's turboprop aircraft. Smaller versions of these vehicles would be limited to cruise altitudes below 12 000 feet. Table 3 summarizes the above parameters.

The operational parameters of CTR air services are conditioned by the fact that the advantages of the tiltrotor lie in its combination of vertical operational ability and high horizontal cruise speed. Since this flexibility carries a higher vehicle cost than for CTOL, its application will be in uses and markets where the extent and value of the time savings offset the relative increase in costs. The critical operational parameters relate to passenger capacity, range, cruise speed, vertical operational ceiling (HOGE), OEI procedures, climate and descent operations, vertiport and CNS infrastructure requirements.

Since safety and, most particularly, the avoidance of catastrophic accidents is of paramount importance in civil air transport, the tiltrotor aircraft will have to be capable of maintaining operations after suffering a total sudden engine failure following which the pilot must be able to fly the vehicle to a safe landing. For use in public transportation, CTR aircraft must demonstrate performance levels in accordance with FAA certification requirements as specified under Transport Category A. According to these regulations, if one engine fails at any time after start of take-off, the vehicle must have the ability to perform the following maneuvers with the remaining power available: (1) return and land safely or (2) continue the take-off and climb out of ground effect (OGE) at a minimum rate of 100 ft/min. These are illustrated in Figure 9. If sufficient height is available, the preferred method would be to tilt the thrust vector forward, make a transition to STOL flight, and subsequently land at a suitable conventional or STOL airport. The more critical engine failure, in terms of both aircraft handling and thrust requirements, occurs when the option of making the transition to STOL flight is not available, thereby requiring immediate initiation of a vertical landing.

CTR climb and descent performance is described in the form of maximum take-off and descent angles, which are the direct result of particular combinations of vertical and horizontal (forward) speeds. The steepest angles are associated with the slowest forward speeds. True vertical climb and descent represent limiting cases of 90 degree angles and zero forward speed. Currently there is no consensus on likely values for planning purposes concerning steep approach angles to be used during IFR tiltrotor operations. The FAA and

NASA are in the process of testing approaches as steep as 25 degrees. From the point of view of minimizing the required airspace around vertiports, true vertical operations are the most desirable. If engine power and OEI time ratings are sufficient to permit vertical take-offs and landings from points well above surrounding structures, then the problems related to steep-angles climb and descent manoeuvres are less of an issue. Due to considerations of operational economics, however, vertical landings and take-off, if feasible, would be executed only at sites where no other alternative is possible (Figure 10).

In high density markets, those parameters relating to control and power required for vertical operations will have an impact on the range of choice of sites for downtown services. In low density markets parameters of range and cruise speed will determine the total area that can be covered and thus the effectiveness of the service. Future developments in CTR will include parameters such as true vertical landing and take-off procedures, in terms of vehicle power required, airspace to be protected, HOGE altitude, vehicle control and stability, etc.

**TABLE 3**  
**CTR AIRCRAFT PERFORMANCE**

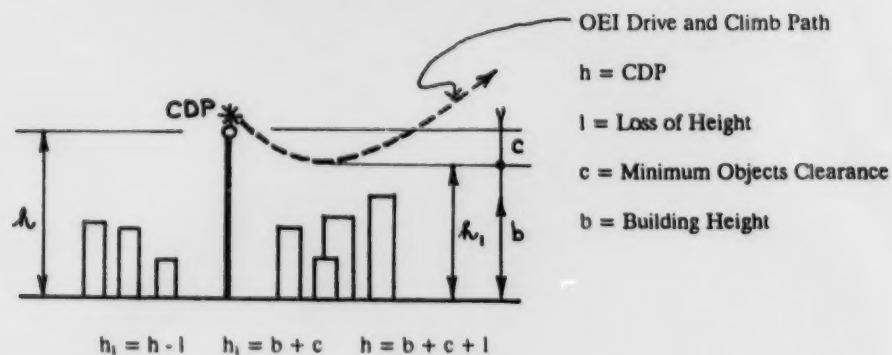
| Aircraft Model |          | Operational<br>Range<br>(nm) | Cruise<br>Speed<br>(knots) | Cruise<br>Altitude<br>(ft) |
|----------------|----------|------------------------------|----------------------------|----------------------------|
| Bell-Boeing    | CTR-22B  | 600                          | 240                        | 10 000                     |
|                | CTR-22C  | 600                          | 282                        | 18 000                     |
|                | CTR-22D  | 280                          | 282                        | 18 000                     |
|                | CTR-800A | 600                          | 273                        | 25 000                     |
|                | CTR-1900 | 600                          | 282                        | 25 000                     |
|                | CTR-7500 | 600                          | 300                        | 26 000                     |
| EUROFAR        | baseline | 665                          | 335                        | 24 600                     |
| Ishida         | TW-68    | 700                          | 268                        | n.a.                       |
| Magnum         | MTR-201  | 865                          | 350                        | 30 000 +                   |

**FIGURE 9**  
**CTR TAKE-OFF / OEI PROCEDURES**

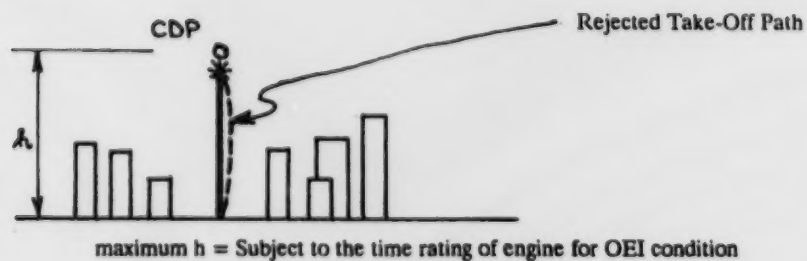
STANDARD TAKE-OFF / CLIMB PATH



ENGINE FAILURE ABOVE CDP



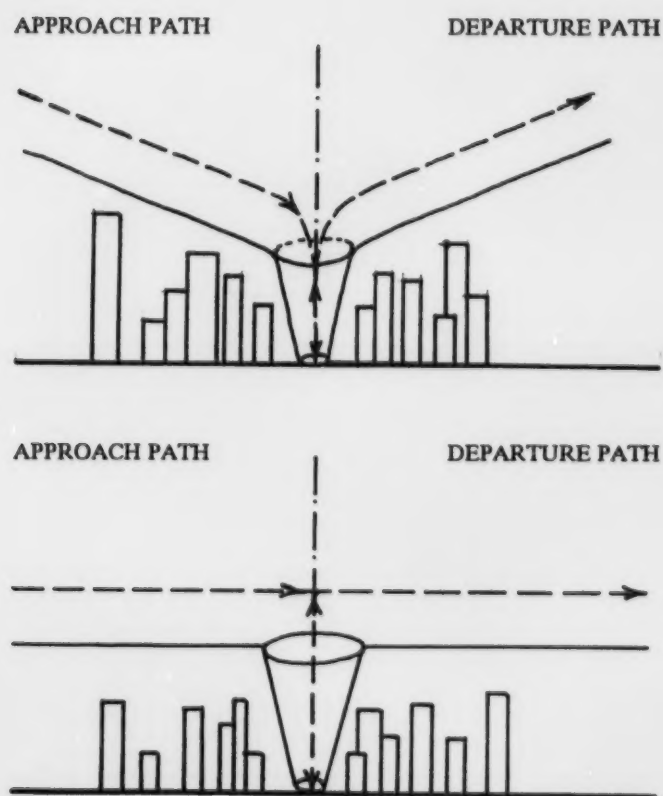
ENGINE FAILURE BELOW CDP



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**FIGURE 10**  
**VERTIPORT PROTECTED AIRSPACE - VERTICAL LANDING AND TAKE-OFF**

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## 2.4 Air Navigation System

Broadly defined, the air navigation system represents the infrastructure required to manage an aircraft from the time that it leaves a parking area at the point of departure until the time that it terminates its flight at the destination. With respect to CTR operation, the air navigation system requirements are a function of the way in which the vehicle will operate in the airspace environment under different missions. The implementation of CTR air services would require the establishment of distinct elements of aeronautical and airport infrastructure to support the new services and derive maximum benefit from the enhanced operational characteristics of the vehicle. Provisions for accommodation of tiltrotor operations will involve the following components of the overall airspace system architecture:

- . En-Route Airspace
- . Terminal Control Area
- . Flight Paths
- . Missed Approaches
- . Holding Areas
- . Vertiport Protected Airspace

The integration of CTR into the existing air navigation system will require the establishment of designated air routes within air terminal areas in order to ensure independent operations and thus to maximize the potential benefits of the new technology in terms of improving safety and capacity in congested terminal airspace environments. CTR service will not require the establishment of dedicated airways outside terminal control zones. In-flight performance and characteristics are comparable to turboprop aircraft; CTR, therefore, can share currently established CTOL air routes.

The introduction of CTR technology is expected to have a positive impact on the overall capacity of the existing air navigation system, especially in the critical terminal area. This expectation is based on the fact that, due to their enhanced manoeuvrability, CTR aircraft will be capable of utilizing airspace not suitable for fixed-wing craft. Special designated air routes, holding areas, procedures for missed approaches and vertiport protected areas will have to be established within Terminal Areas (Table 4). CNS (Communications, Navigation and Surveillance) Support Systems will be established to support these services, with particular emphasis on vertical MLS and GPS.

Experts in the U.S. have estimated that "full development and certification for operational use of tiltrotor technology could occur in the 2000-2005 time frame". Most of the data available today in the area of air navigation requirements for the tiltrotor exists as a result of work completed and in progress in the U.S. and, to a lesser extent, in Europe.

**TABLE 4**  
**VFR AND IFR PROTECTED CTR AIRSPACE REQUIREMENTS**

| Protected Airspace<br>Imaginary Planes | VFR              | Operations<br>IFR |
|----------------------------------------|------------------|-------------------|
| <b>Primary Surface</b>                 |                  |                   |
| shape                                  | FATO             | FATO              |
| size                                   | FATO (2)         | FATO (2)          |
| elevation                              | TLOF             | TLOF              |
| <b>Approach/Departure Surface</b>      |                  |                   |
| shape                                  | trapezoid        | trapezoid         |
| width - lower edge                     | FATO             | FATO              |
| - upper edge                           | 195 m (650 ft)   | 1500 m (5000 ft)  |
| length (3)                             | 1200 m (4000 ft) | 3000 m (10000 ft) |
| elevation - lower edge                 | TLOF             | TLOF              |
| - upper edge                           | 150 m (500 ft)   | 300 m (1000 ft)   |
| slope                                  | 8 : 1            | 10 : 1            |
| <b>Transitional Surface</b>            |                  |                   |
| shape                                  | triangular       | trapezoid         |
| width (3) - lower edge                 | 60 m (200 ft)    | 180 m (600 ft)    |
| - upper edge                           | 0                | 420 m (1400 ft)   |
| length (3)                             | 1200 m (4000 ft) | 3000 m (10000 ft) |
| slope                                  | 2 : 1            | 7 : 1             |

- (1) visual and non-precision  
(2) minimum 75 m x 75 m (250 ft x 250 ft)  
(3) horizontal dimension

## 2.5 Vertiports

Implementation of CTR air services would go hand-in-hand with the development of a specialized type of "vest-pocket" airport - the vertiport. These would be small-scale facilities which would exploit the vertical take-off and landing capabilities of the CTR vehicle by being located close to the centres of demand (urban core areas, intermodal traffic hubs, other airports, etc.). Their facilities would tend to resemble those of heliports, since the take-off and landing manoeuvres, executed in proximity to the terminal area, will generally be performed in the helicopter mode; in fact, in many cases, the same VTOL site will probably serve both helicopter and tiltrotor operations.

In order to take the fullest advantage of the vertical flight characteristics of tiltrotor aircraft, new minimal airport facilities will be required, which will enable the extension of services and of the range of sites, especially within urban areas. These will be located in a variety of contexts such as central business districts, waterfronts, rooftops, suburban highways, even co-located at airports. Although a number of sites will derive the greatest value from the minimal land area requirements of tiltrotor aircraft, the possibility of accommodating rolling take-off procedures would improve range and payload ratings of the vehicle.

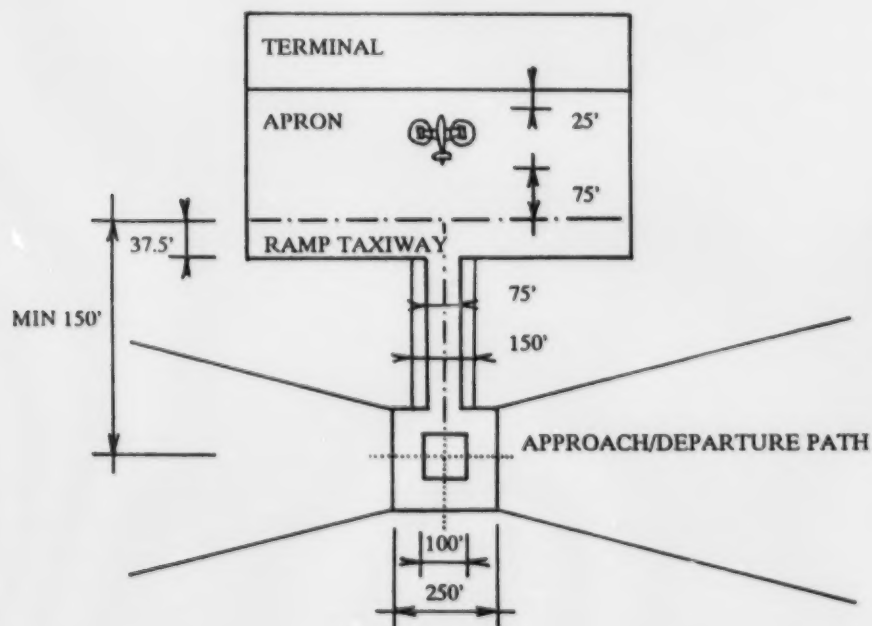
Preliminary vertiport standards are being developed under the aegis of the FAA by a joint industry-government task force. Similar in many respects to helicopter and heliport standards, these standards take into account that CTR, as an intercity commercial passenger service, would require provision for appropriate passenger facilities and airline-type gate operations.

The nature and extent of facilities to be provided at a given vertiport are a function of the types of CTR air services to be accommodated and the location and general characteristics of the vertiport in question. In terms of basic planning and design principles, the facilities required to serve the needs of CTR air services will have many similarities to those of typical small airports: simple, straight-forward flow patterns, multi-functional use of space, flexibility with respect to expansion and modification. They will also reflect the requirements and preferences of the expected clientele for CTR service: a time-sensitive business-related, affluent market making short-distance, short-duration trips.

In comparison with other sectors of the air travel market, these passengers will typically spend less time in the terminal building both arriving and departing, carry their baggage rather than check it, travel in smaller groups, use taxis as a prime mode of ground access, etc. In general these passengers will resemble the clientele for STOL services as documented in the reports **STOL Demonstration Montreal-Ottawa 1974-76 (TP 1687 and TP 1688)** and **STOLport Research and Applications (TP 5986)** published in 1978 and 1985 respectively (Figure 11).

Only those vertiports with sufficient land area (land-based/single-level sites and co-located at airports) will include full-service aircraft maintenance facilities. The relatively extensive space requirements of such facilities will preclude their location at downtown vertiports. Only overnight aircraft maintenance and emergency repairs will be performed at these sites, and these operations will take place at the aircraft parking positions. At less constrained sites, hangars in which aircraft maintenance is done may also serve for aircraft storage at night.

**FIGURE 11**  
**TYPICAL VERTIPORT FACILITIES**



## 2.6 Environmental Considerations

If CTR air services are to fulfill their promise of providing enhanced point-to-point air service in a wide variety of contexts, including dense urban areas, they will have to demonstrate their environmental compatibility. In Canada, a number of federal, provincial and municipal statutes require that projects such as the construction of vertiports/heliports or the introduction of new transportation services such as CTR submit to an environmental review before obtaining certification, funding and/or authorization for implementation. The most publicized environmental concern with respect to CTR service is the same as that for other rotorcraft: noise. Other environmental concerns include flight safety, fire protection and generation of ground traffic, especially in urban settings, where proper planning of CTR facilities and services and public awareness education should enable the integration and acceptance of tiltrotor in the environment.

The dynamics of noise generation and propagation by tiltrotors are highly complex, similar to helicopters in vertical flight and turboprops in horizontal flight (Figure 12). NASA and the FAA are developing prediction models for advanced rotorcraft such as the tiltrotor, based on a better understanding of these dynamics as a result of tests on actual vehicles such as the V-22. Indications are that the extent and severity of the noise impact of tiltrotors will be significantly less than for helicopters, due to the relatively short time that the vehicle will spend in vertical mode (Figures 13 and 14).

Air pollution represents one of the potential environmental concerns relative to all forms of air transportation and in this sense CTR air services are no different from others. At present knowledge of the extent of aircraft emissions from the full range of expected CTR vehicles is limited to experience with the XV-15 and the V-22 and to design data for the various other models. In the case of tiltrotor operations, air pollution is generated essentially by two sources: (1) engine emissions and (2) turbulence-induced dust during lift-off and touch-down manoeuvres. According to the NASA study of 1987, the engine emission levels for CTR aircraft are expected to be acceptable and will not contribute significantly to general levels of air pollution. With respect to dust raised by the rotor down-wash and ground turbulence during lift-off and touch-down, neither the volume generated nor the area affected is expected to be significant. The effect of these phenomena is easily controllable by effective design of the vertiport airfield surfaces and proper operational practices, thus limiting or virtually eliminating the danger of surface erosion and the formation of dust clouds during landing, take-off and hover taxi operations.

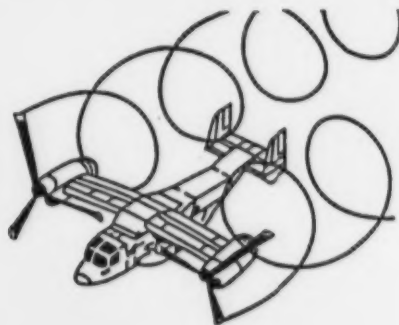
Energy consumption by tiltrotor aircraft constitutes a further environmental concern. In general terms, the direct consumption of energy for propulsion will be higher for tiltrotor than for other aircraft, although many of the indirect components of energy consumption will be lower (Table 5). The net difference will depend on the particular characteristics the service in question.

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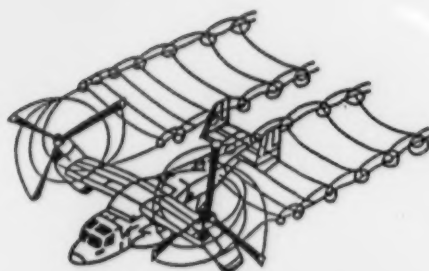
**FIGURE 12**  
**TILTROTOR WAKE FLOW PATTERNS**

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AIRPLANE MODE



TILT ROTOR MODE



HOVER MODE

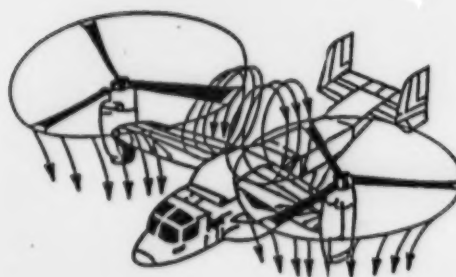
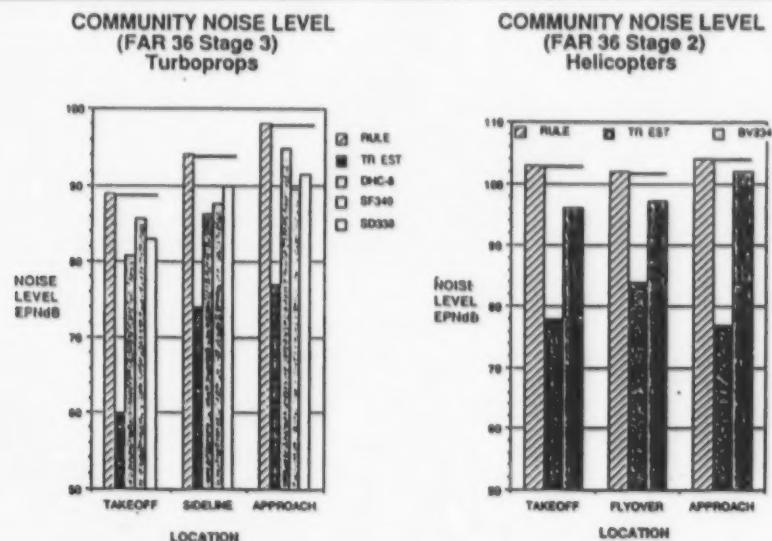


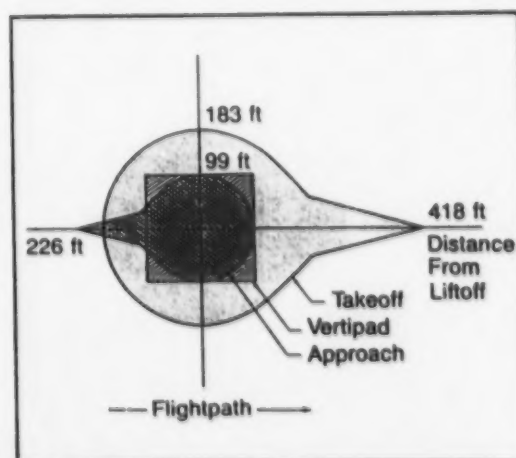
**FIGURE 13**  
**TILTROTOR/VERTIPORT NOISE**



SOURCE: NASA

**FIGURE 14**  
**GROUND-LEVEL NOISE CONTOUR FOR A TYPICAL CTR**

Community Noise Levels



Noise Profile (80 dBA Contours)

SOURCE: NASA

**TABLE 5**  
**ENERGY CONSUMPTION BY MODE FOR SHORT-HAUL INTERCITY**  
**PASSENGER TRAVEL**

|                                                       | CTR<br>22C | CTR<br>7500 | AIR<br>TURBO | AIR<br>JET | RAIL<br>LRC | INTERCITY<br>BUS | AUTO-<br>MOBILE |
|-------------------------------------------------------|------------|-------------|--------------|------------|-------------|------------------|-----------------|
| <b>Direct Energy</b>                                  |            |             |              |            |             |                  |                 |
| Vehicle Propulsion<br>(kj/seat-km)                    | 2774       | 1935        | 1207         | 1387       | 406         | 386              | 558             |
| <b>Indirect Energy</b>                                |            |             |              |            |             |                  |                 |
| Energy Production<br>and Distribution<br>(kj/seat-km) | 349        | 244         | 152          | 175        | 51          | 49               | 109             |
| Vehicle Production<br>(kj/seat-km)                    | 61         | 61          | 29           | 29         | 33          | 20               | 185             |
| Vehicle Maintenance<br>(kj/seat-km)                   | 181        | 181         | 90           | 90         | 64          | 52               | 115             |
| <b>Infrastructure</b>                                 |            |             |              |            |             |                  |                 |
| Construction                                          |            |             |              |            |             |                  |                 |
| Terminal<br>(kj/pax)                                  | 16 600     | 16 600      | 16 600       | 41 000     | 46 215      | 9 140            | n.a.            |
| Civil<br>(kj/seat)                                    | 6 000      | 6 000       | 18 000       | 64 000     | 865         | 80/km            | 80/km           |
| <b>Infrastructure</b>                                 |            |             |              |            |             |                  |                 |
| Maintenance                                           |            |             |              |            |             |                  |                 |
| Terminal<br>(kj/pax)                                  | 83 000     | 83 000      | 83 000       | 206 000    | 98 430      | 15 800           | n.a.            |
| Civil<br>(kj/seat)                                    | 1 167      | 1 167       | 3 500        | 9 640      | 63/km       | 10/km            | 10/km           |
| <b>Access</b>                                         |            |             |              |            |             |                  |                 |
| (kj/pax)                                              |            |             |              |            |             |                  |                 |
| Mtl-Tor.                                              | 52 020     | 52 020      | 156 060      | 156 060    | 55 080      | 58 140           | n.a.            |
| Tor.-Ott.                                             | 52 020     | 52 020      | 146 880      | 146 880    | 55 080      | 52 020           | n.a.            |
| Mtl-Ott.                                              | 36 720     | 36 720      | 88 740       | 88 740     | 36 720      | 36 720           | n.a.            |
| Mtl-Que                                               | 36 720     | 36 720      | 107 100      | 107 100    | 39 780      | 36 720           | n.a.            |

## 2.7 Application in Canada

Based on an extensive and comprehensive market analysis, and also on an evaluation of CTR technology, the FAA, NASA and others have concluded that a commercial tiltrotor operation is technically feasible, economically competitive and has a potentially significant role to play in civil air transportation. Due to its unique capabilities and enhanced in-flight characteristics, the CTR vehicle offers significant advantages in a number of applications when compared with conventional fixed-wing or rotating-wing aircraft. The NASA/Bell-Boeing studies **Civil Tiltrotor Missions and Applications: A Research Study** (1987), and **Phase II: The Commercial Passenger Market** (1991) as well as other documents, identified the following specific areas in which the application of CTR technology would seem to offer advantages over other modes of transportation:

- . Short-Haul Commercial Air Passenger Market
- . Resource Development Market
- . Public Service Market
- . Corporate/Executive Market
- . Cargo/Package Express

The application of CTR in Canada can be divided into commercial intercity passenger service on the one hand and a variety of other likely missions on the other. The present study concentrates on the high-density city-centre to city-centre short-haul markets in order to identify city pairs which, because of their particular interdependence, geographical relationships and the level of air passenger travel demand they generate, could likely benefit from introduction of regular CTR service.

CTR service would not be intended to replace all present CTOL service on short-haul air routes. This is neither practical nor desirable. A number of short-haul flights are in fact legs of longer routes; also a number of air passengers use short-haul flights to connect to other destinations. CTR intercity service would be intended to cater to a specific segment of the market by offering a new type of air service which conventional fixed-wing turboprop and jet aircraft cannot offer.

The application of the basic service parameters listed in Table 6 enables the determination of a minimum size for a commercial CTR operation which would satisfy the basic CTR service criteria. More specifically, tiltrotor passenger services are most likely to find application in the dense short-haul markets of the Quebec-Windsor corridor, with connections to similar markets in the Northeast U.S. Such a market could account for some seven million passenger arrivals and departures in the year 2000 and some 10 million in 2010.

**TABLE 6**  
**SUMMARY OF CTR MARKET ANALYSIS CRITERIA AND PARAMETERS**

|                                                         |                   |
|---------------------------------------------------------|-------------------|
| Aircraft seating capacity                               | 39 seats          |
| Aircraft effective range <sup>1</sup>                   |                   |
| . minimum air route length                              | 185 km            |
| . maximum air route length                              | 356 km            |
| Average block time                                      | 60 min            |
| Daily operating hours                                   | 07h00 - 22h00     |
| Minimum required service frequency                      |                   |
| . to initiate CTR service <sup>2</sup>                  | 30 min            |
| . to expand CTR service <sup>3</sup>                    | 60 min            |
| Variation in level of service<br>weekday vs weekend day | 3 : 1             |
| Number of weekdays in a year                            | 250 days          |
| Average annual utilization per aircraft                 | 2300 hours        |
| Average annual load factor                              | 70%               |
| Penetration of CTOL O/D air market                      |                   |
| . 30 min frequency of service                           | 2/3 of the market |
| . 60 min frequency of service                           | 1/3 of the market |

<sup>1</sup> Effective range from a marketing point of view vis-à-vis other available modes of travel.

<sup>2</sup> Establishment of new vertiports at both ends of a route.

<sup>3</sup> Expansion of CTR service based at an existing vertiport and establishment of a new vertiport at the new service point.

In particular, the following city pairs were found to comprise an integrated and identifiable market for tiltrotor commercial intercity passenger services oriented essentially toward business and other travellers who value time and total door-to-door convenience most highly and therefore derive the greatest benefit from these services (Figure 15).

|          |   |            |
|----------|---|------------|
| Montreal | - | Toronto    |
| Toronto  | - | Ottawa     |
| Montreal | - | Ottawa     |
| Montreal | - | Quebec     |
| Toronto  | - | New York   |
| Montreal | - | New York   |
| Toronto  | - | Washington |

In order to be commercially successful, CTR service would have to meet certain criteria necessary to ensure the unique competitive advantages of the technology. A large segment of the potential CTR clientele consists of business people travelling between major commercial centres. Their key concern is time. Therefore, a successful CTR service would have to be oriented towards minimizing overall door-to-door travel time. The following parameters will have direct influence:

- **Vertiport physical location** - Vertiports would have to be located close to the markets they serve in order to minimize time and out-of-pocket expenses related to the ground portion of the over-all door-to-door trip and, thus, to maximize the CTR market potential. The present study does not include the evaluation of the availability of appropriate vertiport sites in the specific Canadian cities identified as potential candidates for CTR service. It is assumed that such sites would be available.
- **Vertiport intermodal integration** - Vertiports would have to be well integrated into the local multi-modal transportation network in order to function effectively as an inter-modal transfer point. All forms of local transportation must have convenient and easy access to the local vertiport in order to maximize market exposure. The study assumes that all vertiports under consideration will be adequately integrated.
- **CTR level of service** - A combination of aircraft seating capacity and frequency of service defines the minimum market size required to support CTR service. In order to be commercially successful, the capacity of the CTR system would have to be carefully tuned to the actual size of the market being served and would have to offer a frequency of flights competitive with parallel CTOL services. For the purpose of this study, an aircraft size of 39 seats and frequency of service of 30 and 60 minutes are used.
- **CTR all-weather capability** - CTR service would have to offer all-weather, reliable and safe service comparable to that of CTOL. In fact, the special capability of the tiltrotor to independently control vertical and horizontal speed of movement in the final

approach provides greater potential for all-weather landings than CTOL aircraft. The study assumes that all scheduled services will be operating under IFR regime.

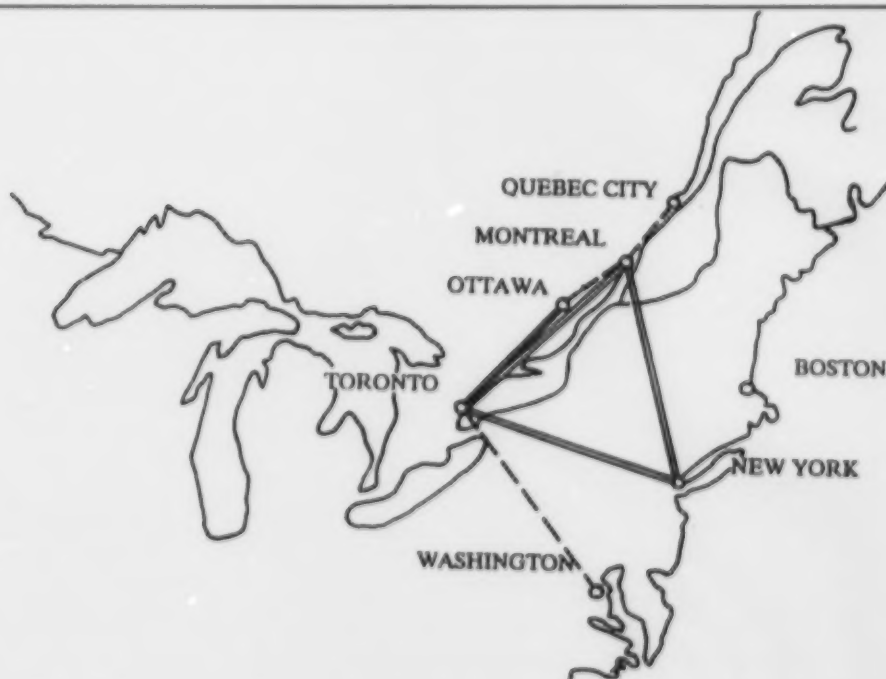
**CTR airspace** - On a national basis, regional tiltrotor networks serving the major metropolitan areas, including the heliports and hub airports, will have to be designed and put into place to allow safe and reliable operations into urban centres and busy airports on a non-interference basis in order to realize the potential of reducing air traffic delays on a system-wide basis. The present study assumes that no difficulties will be encountered in the establishment of the most direct and safe air routes to be allocated for scheduled tiltrotor service.

**Passenger comfort** - CTR service will have to offer all amenities and services now provided by CTOL service. Passenger and baggage handling procedures at vertiports will have to be streamlined in order to minimize in-terminal time, thus reflecting the fact that the service would be geared to those clients who assign a high value to their time. The study assumes that the overall level of passenger comfort will be at least equivalent to that of CTOL business class.

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**FIGURE 15**  
**POTENTIAL MAJOR CANADIAN INTERCITY CTR MARKETS**

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In order for CTR commercial passenger service to fulfil its role as a premium short-haul transportation mode, it would have to present both real and perceived differences in the efficiency of the service relative to other available short-haul travel modes. The ultimate goal of providing multiple-point services in metropolitan areas would be developed in stages, starting with centre-to-centre services. In addition to its attractiveness and significance as a vehicle for short-haul commercial air passenger transportation in high density markets, there are a number of other potential applications of CTR technology in Canada:

**Air Passenger Service to Remote Regions:** The ability of tiltrotor aircraft to fly medium-range missions at turboprop speeds with virtually no runway requirements points to a potentially valuable role for CTR as a vehicle to enhance and extend the reach of air passenger service in remote regions. The vast majority of the area of Canada falls into this category. This is especially true in the northern regions, where the air mode is already well established as the only practical means of year-round transportation of persons and goods. The use of tiltrotor technology as a replacement for fixed-wing aircraft would substantially reduce the construction and maintenance costs of airport facilities, by minimizing runway length requirements and lowering the stringent requirements relative to surface conditions of landing areas.

**Support of Resource Exploration and Development:** This market in Canada consists essentially of off-shore oil and gas exploration and development, logging, mining and general resource exploration. Perhaps the best potential for immediate introduction of CTR is in air support of oil and gas exploration and development. Air support is a critical transport mode used for moving personnel and supplies between off-shore platforms and the on-shore support and supply bases. The current state-of-the-art air transportation in off-shore development is represented by the familiar helicopter shuttle services now operating between platforms and on-shore staging centers and supply bases in various parts of the world. In fact, this is the most successful world market for large helicopters. A major problem associated with helicopters is a significant loss of productivity when longer trip stage lengths are involved. Average cruise speed and maximum flight range are two limiting factors.

**Public Services:** The public services market places the greatest demand on the capabilities of the vehicle, due to the wide range of different types of missions required to be performed in this market.

**Medical Transport** - the use of CTR would improve the efficiency of missions currently requiring transfers between helicopters and fixed-wing aircraft for total trip stage lengths beyond the range of helicopters.

**Forest Fire Fighting / Disaster Relief / Search and Rescue** - CTR has been identified as a potentially beneficial technology in the areas of forest fire fighting, disaster relief and search and rescue, due to the ability of the aircraft to cover a wide area of territory, remain aloft for long periods of time, fly at the speed of turboprops, hover and perform precise vertical landings and take-offs.

**Maritime and Border Patrol** - The same characteristics which render CTR attractive as a support vehicle for emergency intervention and resource development favour its use for maritime and border patrol missions.

**Corporate / Executive Air Service:** The potential for application of CTR technology in the corporate/executive market is substantial. The 1987 NASA/Bell-Boeing Study estimated that some 650 units will be required by the year 2000 to satisfy worldwide demand. In fact, according to the authors of the above-mentioned study, this sector represents the second largest single market after that of commercial air passenger service.

**Air Cargo / Package Express Services:** The primary advantage of CTR utilization in this market lies in its capability to deliver goods by air faster and closer to their final destinations than under the current system. In order to take advantage of CTR services in this market, the operator would benefit from the existence of strategically located vertiports, easily accessible by road during night hours. The CTR market potential for cargo/package express in Canada seems to be limited to a few inter-city markets parallel to those identified as possible markets for commercial passenger service. It seems to be reasonable to assume that the development of this CTR market could start as an extension of CTR air passenger express/package services in the U.S. Using the aircraft for passenger service during the day and for package express service during the night would improve the total daily utilization of the vehicle. Dedicated aircraft would likely be introduced once the service is well established and proven.

